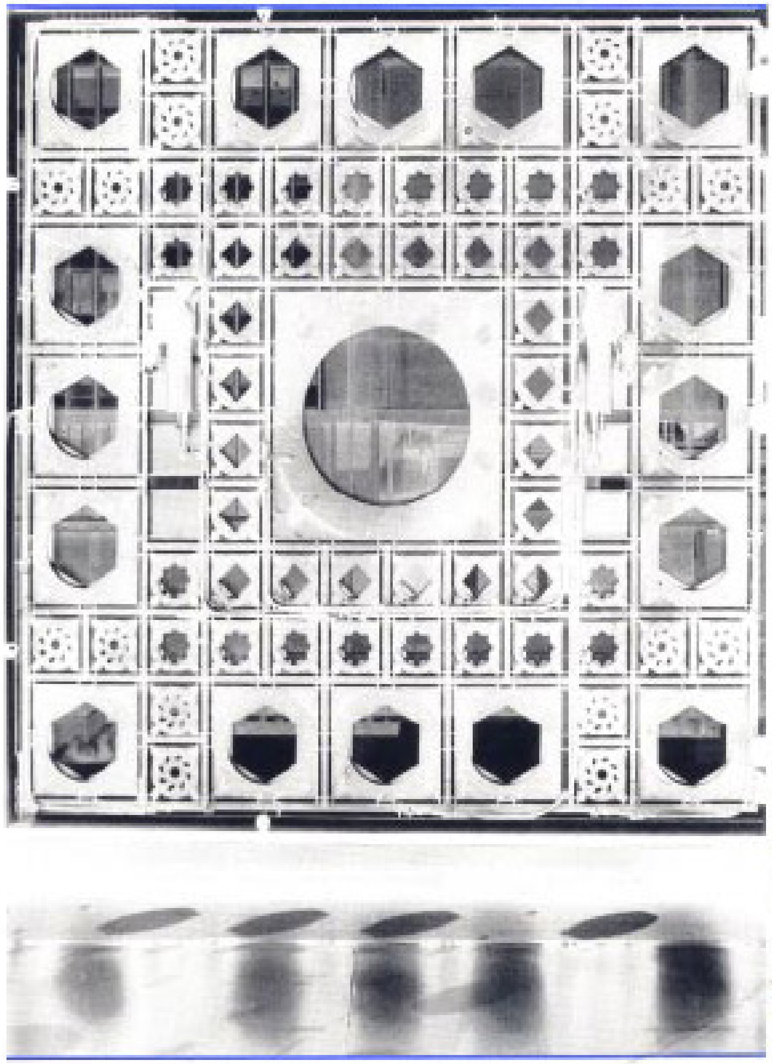
INSIDE Out

Second Edition



DESIGN PROCEDURES FOR PASSIVE ENVIRONMENTAL TECHNOLOGIES

A3 - E3 Acoustics

G. Z. Brown
Bruce Haglund
Joel Loveland
John S. Reynolds
M. Susan Ubbelohde

Illustrations by Amy Dowty

A3 ACOUSTICS

PRECEDENTS OF ACOUSTIC RESPONSE A3

INTRODUCTION A3.0

Goal

Use desirable sounds on the site, while minimizing noise (unwanted sounds).

Discussion

Designing a building and site for passive heating and cooling and for natural lighting introduces design elements that have potential conflicts with acoustic design strategies. At the site-scale, openness that allows natural ventilation in the summer and adequate daylighting year-round may also allow off-site sounds, such as freeway noise, to penetrate the site. However, thick vegetation that blocks north winds and water elements for cooling can have acoustic benefits—blocking or masking unwanted sounds.

Open building plans that allow cross-ventilation, winter sun penetration, and extensive daylighting pose a problem for acoustic privacy. Adjacent areas in an open plan must not interfere with each other acoustically.

Thermal masses for passive heating and cooling introduce extensive areas of hard, acoustically-reflective surfaces that contribute to reverberant, "live" spaces that may not be appropriate. However, mass walls are excellent barriers to airborne sound transmission, as are thickly insulated, double-framed walls. Open windows for natural ventilation can allow unwanted sounds to enter the building. They also may allow indoor sounds outdoors, across an open space, and into another window—the ventilation may, therefore, by-pass the acoustic zoning and acoustic barriers.

In this section you will:

1. Investigate precedents of acoustic response in buildings.
2. Generalize principles of acoustic response in climatic and cultural settings.

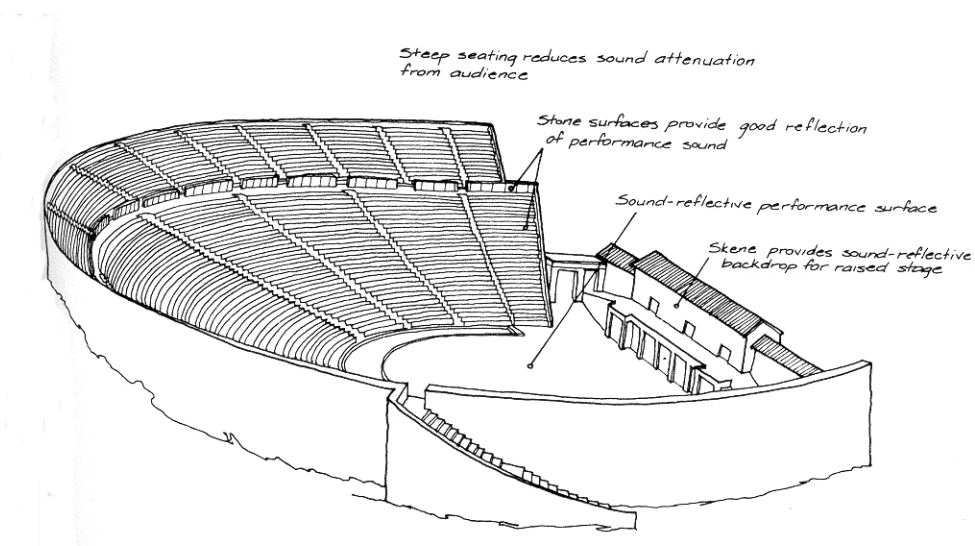


Figure A3.0.1 Typical Greek Theatre, ca. 400–350 B.C.

ACOUSTIC PRECEDENTS A3.1

Acoustic Design Strategies

Cluster-Scale Strategies

- Use buildings or other barriers to create quieter spaces, sheltered from noise sources.
- Provide quiet spaces for quiet uses.

Building-Scale Strategy

- Separate the quiet spaces from the noisy spaces.

Component-Scale Strategy

- Control noise at its source (most economical).

Procedure

Choose an existing building or site that has: (1) a building program that is similar to your assigned building program and (2) a clear, conceptual approach that incorporates some of the acoustic design strategies above.

Document your choice as follows:

1. Identify the location, program, architect (if known), and source of your information.
2. Include photocopies or drawings (whichever is quick and easy for you) to illustrate the design.
3. Evaluate the building or site design with a building response diagram and short annotations that explain how this design is organized to achieve the acoustic goal.

INTRODUCTION

B3.0

Goal

Determine the acoustic properties of your site and what potential benefits or problems may arise. Propose a conceptual design responsive to your climate and site.

Discussion

If you can identify the sound sources on your site and estimate their intensities, you can map the sound levels and identify acoustically favorable and unfavorable indoor and outdoor activity areas.

In this section you will:

1. Plot the sound contours for your site and building.
2. Identify acoustically favorable indoor and outdoor activity areas.
3. Develop an acoustically appropriate site design that takes advantage of features on your site.

SITE SOUND CONTOURS B3.1

Discussion

There are at least three major sources of sound on your site—the freeway, the railroad, and the building itself. There also may be sources unique to your building program (e.g., running or falling water, outdoor activities). Each may be considered as either a linear or a point source of sound. For linear sources, such as the freeway and the railroad, sound is generated along a line. For point sources, such as a waterfall, sound radiates from a single point. In the case of a building, each window behaves as a point source, but a row of windows along the side of a building may be considered collectively as a line source. In any case, the sound level intensity drops 6 decibels with each doubling of distance from the point source (from 50 decibels at 1 foot to 44 decibels at 2 feet, to 38 decibels at 4 feet) and 3 decibels with each doubling of distance from the line source.

Also consider the frequency and duration of sound sources (e.g., the freeway is a constant source with peaks during rush hours, while the railroad is an intermittent source). Decide whether you need to design for the worst case or for normal conditions.

Solid obstructions on your site (e.g., earth berms, wide swathes of trees, walls, and buildings) can provide a small acoustic shadow "downwind" from the sound source.

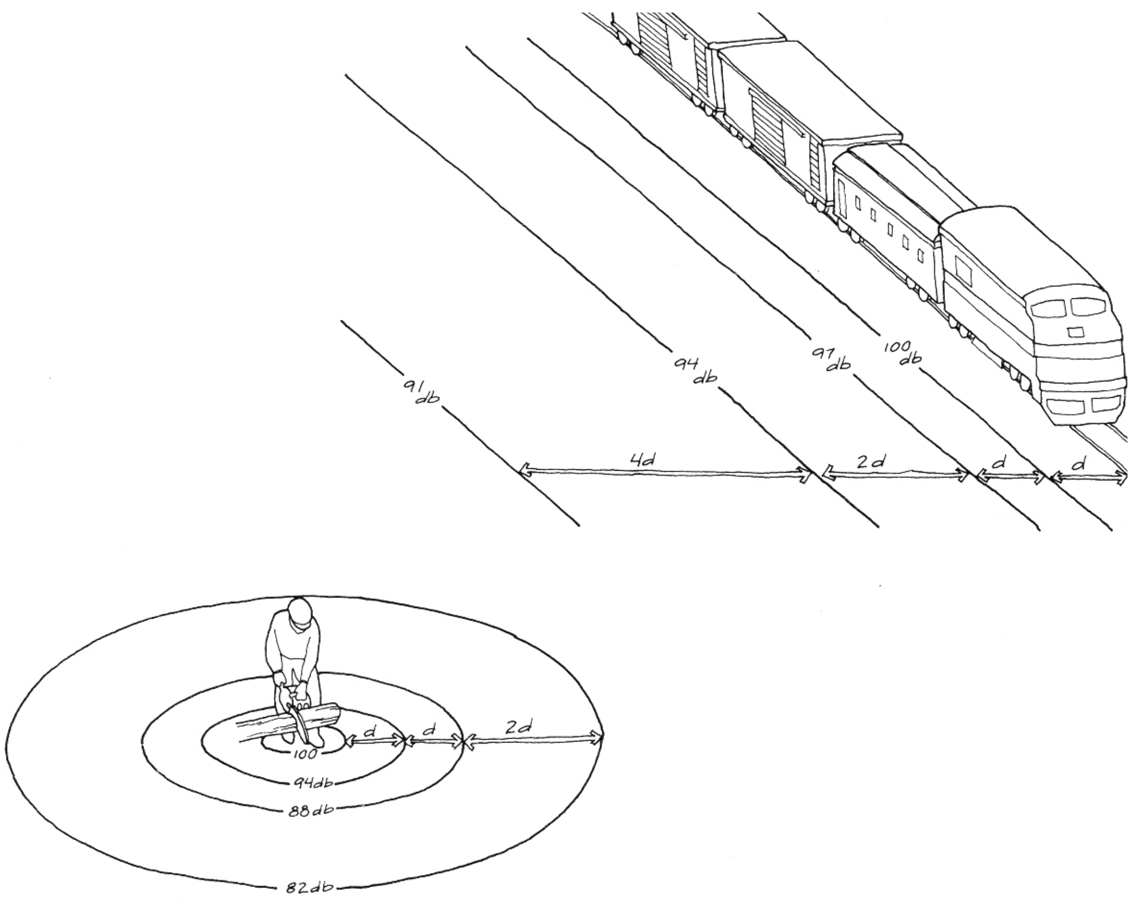


Figure B3.1.1 ***Above***, **Point Source;** ***above right,*** **Line Source of Sound**

PROCEDURE

1. Plot the sound contours for each source (except your building) separately on your site plan.
   a. Color code or plot on a separate sheet of tracing paper each sound source.
   b. Assume a freeway sound level of 60 decibels at a distance of 50 feet; a train sound level of 70 decibels at 100 feet; and an existing solar building sound level of 50 decibels at 10 feet. Other sources may be estimated [*MEEB*, Figure 22.8, p. 1023].

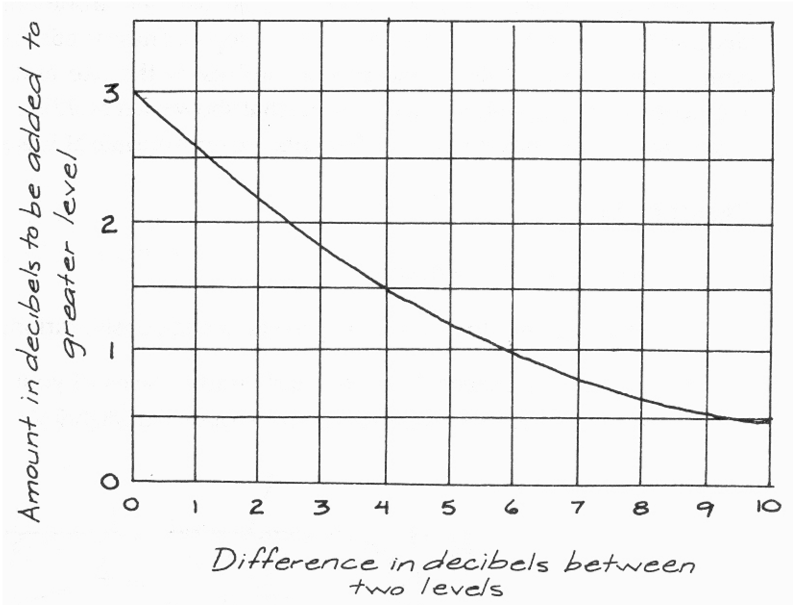


Figure B3.1.2 Nomograph for Adding Decibel Levels

2. Determine the combined sound levels, and plot them at 6-decibel intervals on your site plan.

   Add the decibel levels of overlapping contours (decibels are added logarithmically, so use the chart [Figure B3.1.2] to add the sources).

3. Plot the sound contours of your building on a separate sheet of tracing paper. You may assume a building sound level of 60 decibels at a distance of 1 foot; this sound level is a worst-case assumption for most building types.
4. Overlay all the sound contours, and identify favorable building locations. Mark these locations on your site plan.

SITE CONCEPTS

Discussion

You have gained some insights about the acoustic environment of your site and identified favorable building locations [B3.1, step 4]. These preliminary insights can be synthesized into a design concept that addresses the site and building acoustic interactions. Simple, annotated diagrams that show each building's placement, room organization, and major acoustic elements are appropriate at this stage of design.

Procedure

1. Diagram each site design.
2. Annotate the diagrams to explain acoustic considerations.
3. Discuss the potential benefits and disadvantages of your acoustic concepts with respect to views, thermal control, and daylighting.

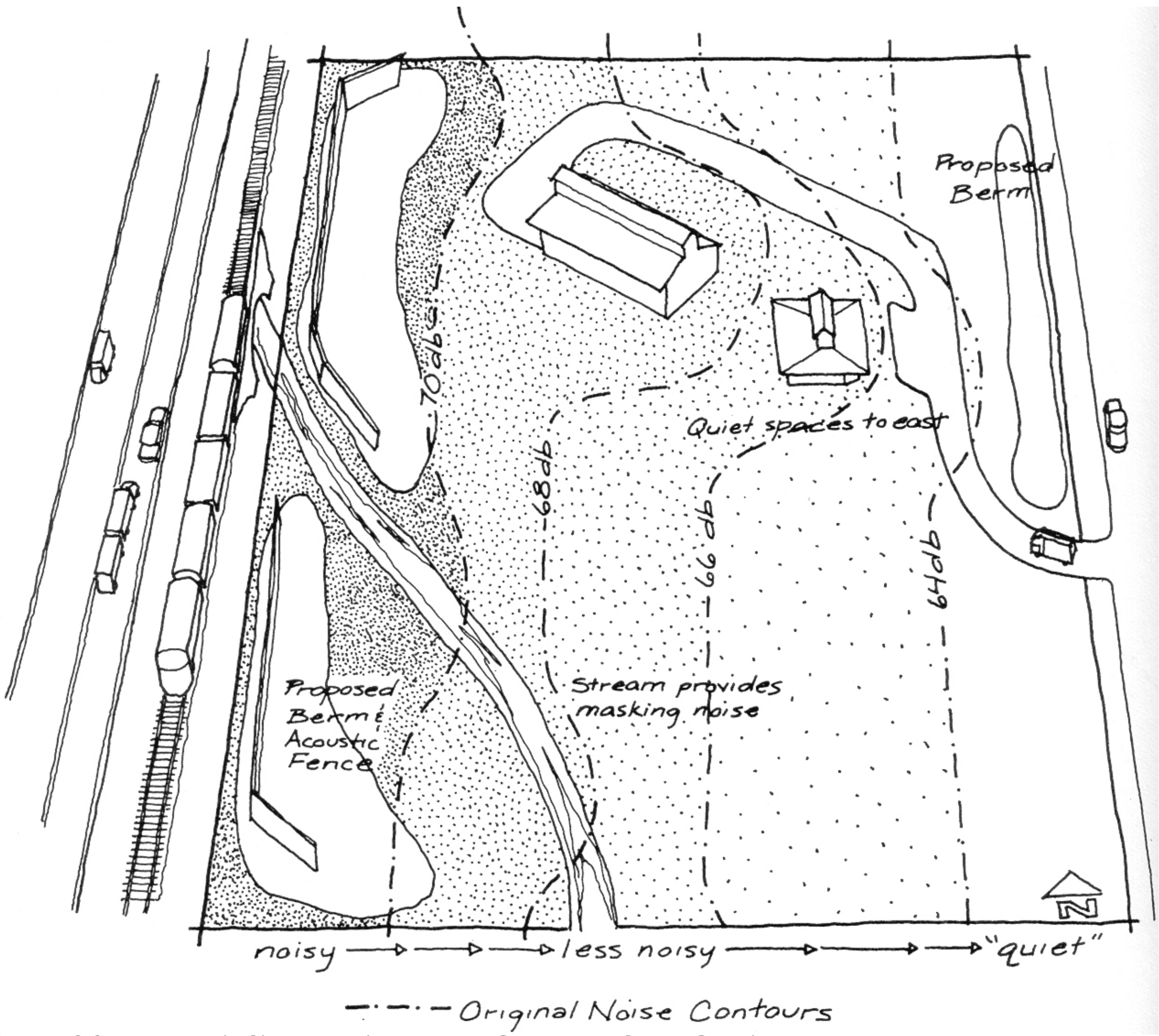


Figure B3.2.1 Acoustic Site Plan. Linen supply, Charleston, South Carolina.

C3 ACOUSTICS

PROGRAM ANALYSIS

INTRODUCTION

Goal

Determine the acoustic requirements of your building, and establish your acoustic zoning strategies.

Discussion

In order to acoustically zone your building, you must analyze the acoustic needs of each space. You can expect different sound levels in the spaces according to their functions. At the same time, you can decide how you would like each space to perform and set its acoustic goals. Using this information, you can determine which spaces are or are not acoustically compatible.

In this section you will:

1. Determine the expected sound level of each space.
2. Set a basic acoustic goal for each space.
3. Propose schematic acoustic zoning for your building.

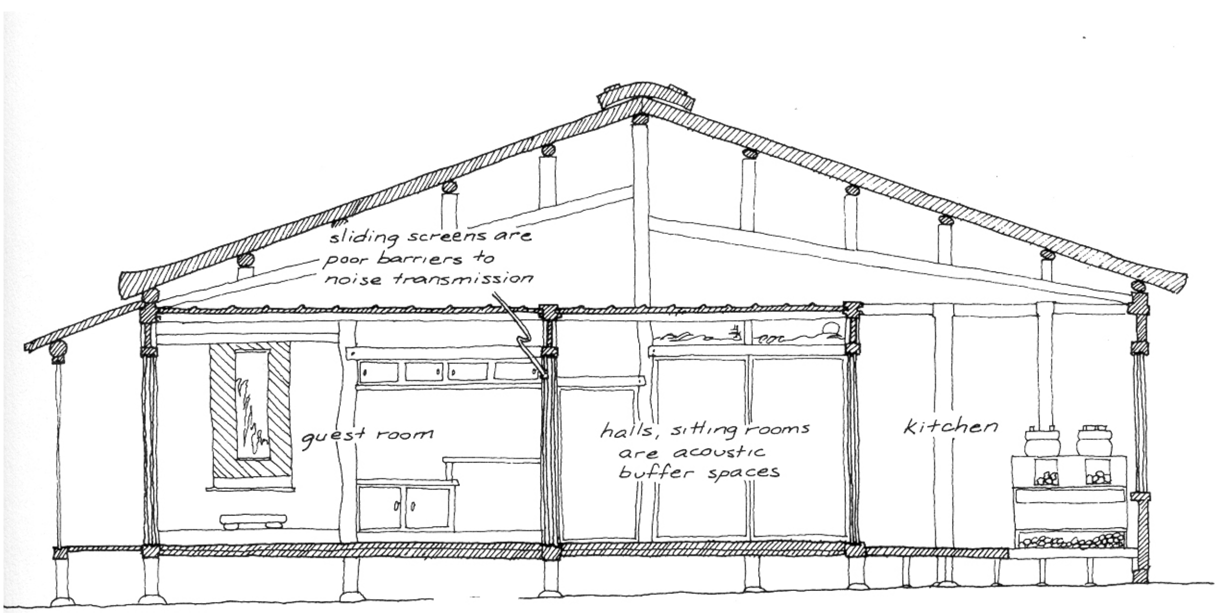


Figure C3.0.1 Acoustic Separation in a Traditional Japanese House

NOISE CRITERIA

Discussion

Noise criteria (NC) set the maximum background noise level for a space according to its function. Low NC (quiet) spaces should be separated from high NC (noisy) spaces, either by distance or acoustic barriers. The greater the difference between NCs, the greater the need for separation. As a guideline, sound levels for spaces whose NCs differ by more than 5 decibels are clearly different; sound levels in spaces whose NCs differ by 10 decibels seem twice or half as loud; and sound levels in spaces whose NCs differ by 20 decibels seem four times or one-fourth as loud.

Acoustic zoning also depends on the acoustic goals in your building. In silence-goal spaces, attention is focused on a single sound source, so background noise must be minimized (e.g., lecture halls and theaters). In quiet-goal spaces, background noise prevents any single sound source from predominating (e.g., offices and grocery stores).

Procedure

1. Determine an NC for each space in your building [*MEEB*, Table 24.8, p. 1107].
2. Decide on an acoustic goal—silence or quiet—for each space.

Noise Criteria [suggested format]

Space	NC (dB)	Silence/Quiet
office	*40–45*	*quiet*

ACOUSTIC ZONING

C3 ACOUSTICS

PROGRAM ANALYSIS

Discussion

In order to acoustically zone the spaces in your building you will have to identify spaces with similar or conflicting acoustic needs. Daylighting and ventilation apertures may also bring in unwanted sound from outside. Your schematic zoning proposal should address the acoustic requirements of all the spaces in your building and should mitigate all potential conflicts.

Procedure

1. Diagram your building, showing the acoustic zoning.
2. Annotate your diagram to indicate the acoustic strategies used and your rationale.
3. Discuss conflicts and harmonies among thermal, lighting, and acoustic needs in your design.

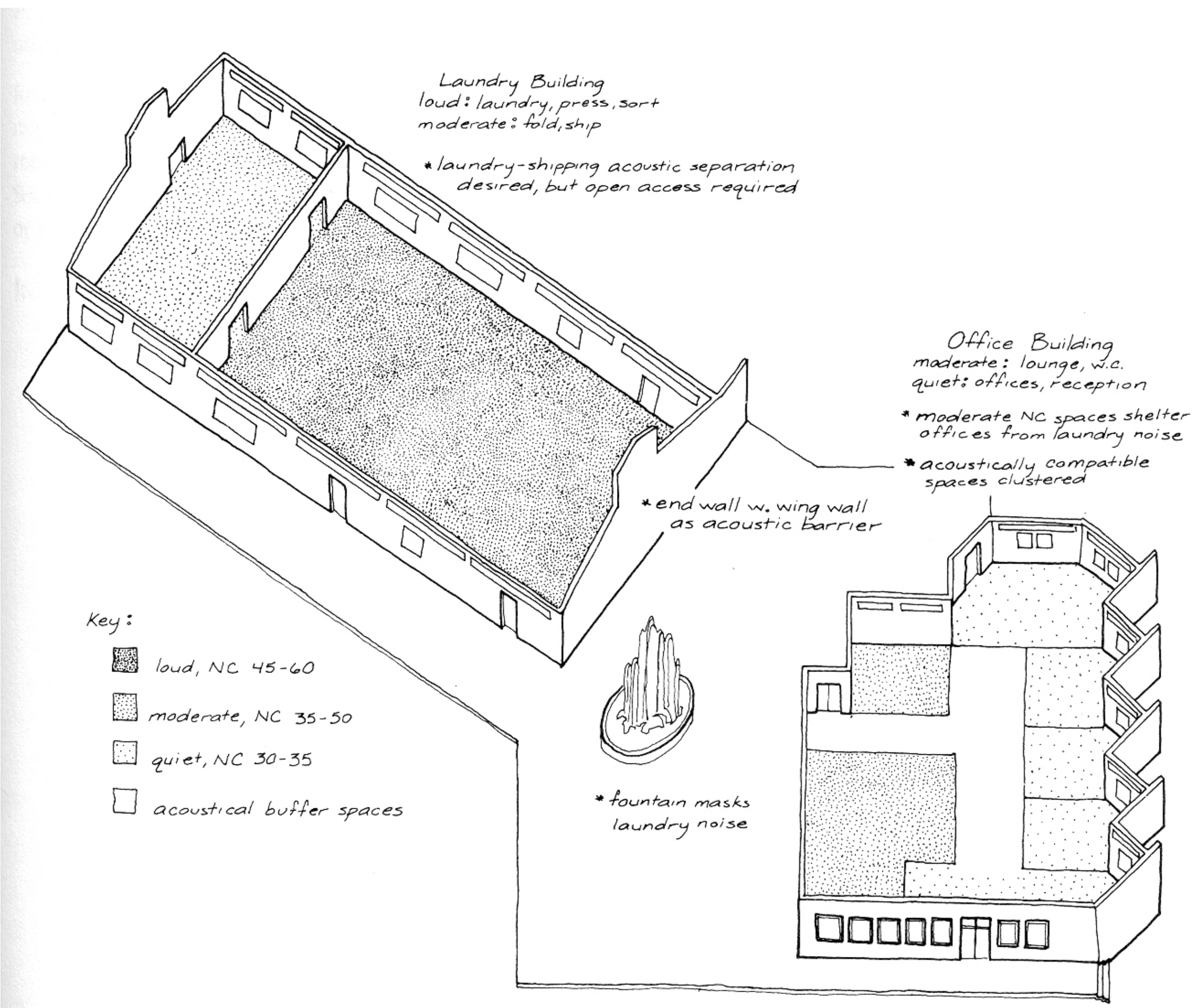


Figure C3.2.1 Acoustic Zoning. Linen supply, Charleston, South Carolina.

D3 ACOUSTICS

SCHEMATIC DESIGN

INTRODUCTION

Goal

Design a building that synthesizes the information you have acquired through the study of precedents; the analyses of your site, climate, and program requirements; and the application of acoustic design strategies.

Acoustic Schematic Design Goals

A. Potential site-scale acoustic conflicts are avoided.
B. Sound conflicts in each space are avoided.

Discussion

The acceptable background noise level in a space is indicated by its noise criteria (NC). Spaces with perceptually different, acceptable, background noise levels (>5 decibels) must be acoustically separated from each other. In most cases, acoustic walls are sufficient for this purpose. Wall and ceiling construction is rated according to its ability to reduce sound transmissions, sound transmission class (STC) [*MEEB,* Appendices K, pp.1771–1790]. An STC of 35 means that sound will be reduced by 35 decibels as it passes through the wall. Openings in walls (e.g., windows, doors, pass throughs, utilities) severely reduce the STC.

Rooms that contain machinery, equipment, large groups of people, or vigorous activity may have sound level peaks far above their acceptable background noise levels. These rooms may require special acoustic isolation to coexist harmoniously in your building. Sounds generated on or adjacent to the site may pose noise problems, since windows opened for natural ventilation transmit sound freely.

In this section you will:

1. Employ appropriate acoustic design strategies.
2. Complete your acoustic schematic design.
3. Illustrate the site-scale and interior acoustic features.
4. Visualize the acoustic performance of the site and building components through acoustic renderings.
5. Review and critique your acoustic schematic design.

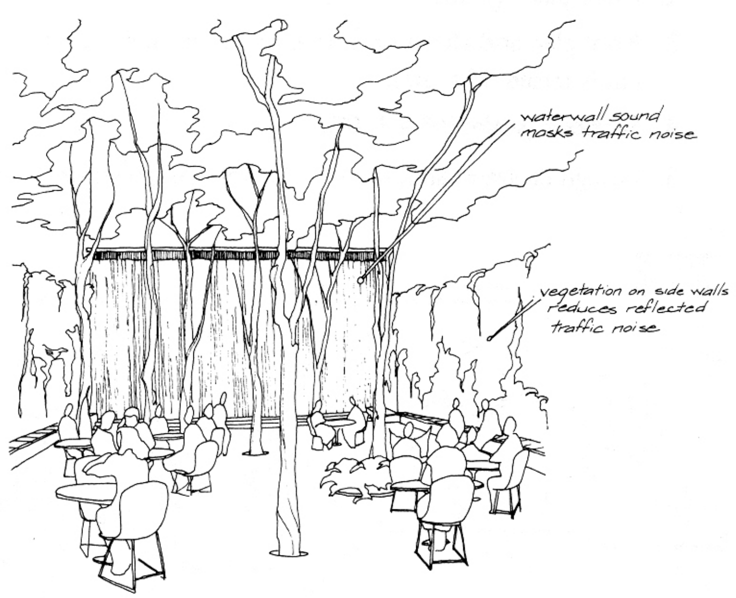


Figure D3.0.1 Water Wall (70 dB). Paley Park, New York, New York, Robert L. Zion (landscape architect), 1966.

DESIGN

Acoustic Schematic Design Strategies

Site-Scale Strategies

- Use natural and manipulated landforms as sound barriers and absorbers.
- Absorb sound with dense, wide (75' minimum) swathes of vegetation.
- Mask unwanted sounds with pleasant, naturally-occurring sounds (e.g., waterfalls, rapids, rustling leaves, birds).
- Place barriers close to the sound source where they will be more effective than barriers close to the receiver.

Building-Scale Strategy

- Separate the noisiest and quietest spaces.

Component-Scale Strategies

- Use thermally massive walls as acoustic barriers.
- Control noise, especially mechanical, at the source.
- Avoid ventilation–acoustics conflicts. Windows are ears to the world. They admit sound readily when open for ventilation.

Procedure

Propose a schematic design for your building based on analyses of precedent [A3], site and climate [B3], and program [C3]. Use the appropriate acoustic design strategies for your design.

Indicate clearly on your drawings your intended acoustic design strategies.

Document your design as follows:

1. Site plan, including parking and access drives (scale: 1" = 100').
2. Floor plans (scale: 1" = 20').
3. Roof plan and elevations, or axonometrics, illustrating all building sides and roofs (scale: 1" = 20').
4. Sections (scale: $^1/_8$" = 1'-0").
5. Design diagram, annotated to identify design strategies and acoustic zones.

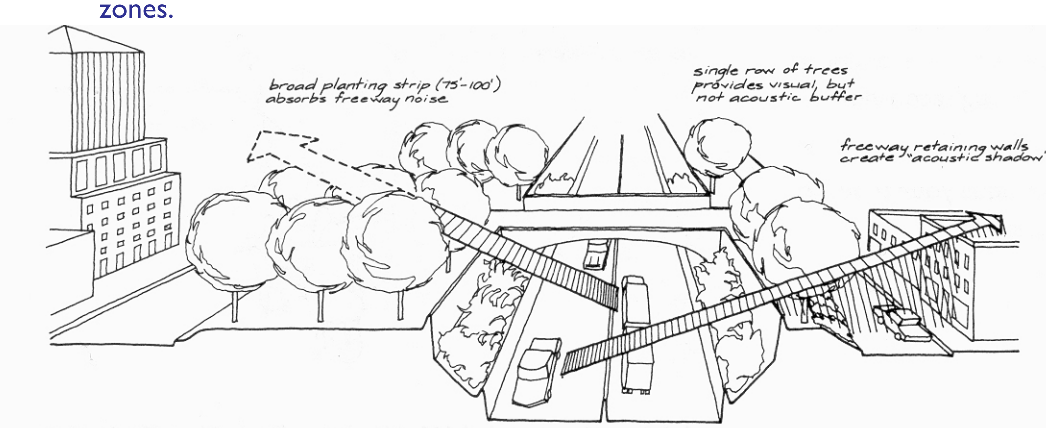


Figure D3.1.1 Acoustic Buffering Techniques in Urban Freeway Design

SCHEMATIC DESIGN

SITE SOUND RENDERING

Discussion

Sounds generated on or adjacent to the site (e.g., by trains, cars, garbage trucks) may conflict with interior noise criteria, especially when windows are open for ventilation. On the other hand, some site sounds (e.g., rustling leaves, waterfalls, fountains) may provide excellent background noise. Berms, dense vegetation, and solid walls may be used at the site scale to mitigate acoustic conflicts. Pleasant sounds may be used to mask equally loud or quieter, unwanted sounds.

Another potential site-scale acoustic conflict may occur when buildings or building wings "see" each other. When the windows are open, sound from one building or wing may cause acoustic disruption in the other.

Procedure

Evaluate how well your building attains Acoustic Schematic Design Goal A—**Potential site-scale acoustic conflicts are avoided.**

1. Draw a section through critical acoustic areas of your site and building.
2. Graphically represent the propagation of sound in the section. Show the direction of propagation, the intensity, and the quality of the sound. There is no graphic convention for representing these sound qualities, so use your imagination to devise a method of representation.
3. Discuss the site-scale strategies used and any design changes you've deemed necessary to meet Goal A. Describe acoustic problems that are not solved at the site scale.

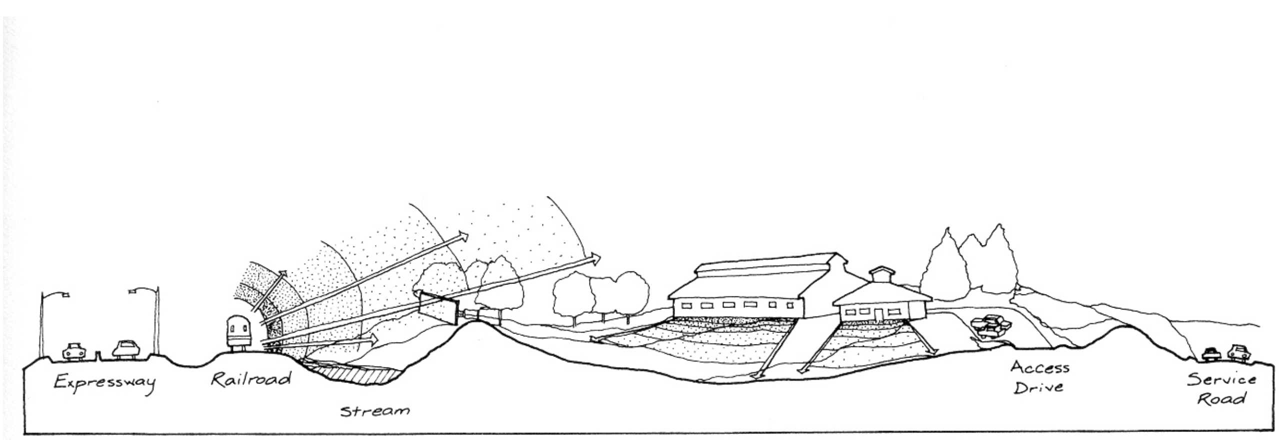


Figure D3.2.1 Acoustic Site Section. Linen supply, Charleston, South Carolina.

THIN-WALL BARRIER D3.3

Discussion

Solid, thin-wall barriers placed near the sound source can reduce (attenuate) the sound significantly. These barriers are most effective when they are as close to the source as possible, as high as possible, and as long as possible. Thin-wall barriers are more effective in attenuating high frequency sounds (e.g., sirens, tire whine) than low frequency sounds (e.g., engine growl). Generally, a thin-wall barrier can be effectively replaced by a berm of similar height or a 75–100' wide barrier of vegetation.

For more information

Egan, *Architectural Acoustics*, pp.253–257 (design procedure description).

Procedure

Evaluate how well your building attains Acoustic Schematic Design Goal A—**Potential site-scale acoustic conflicts are avoided.**

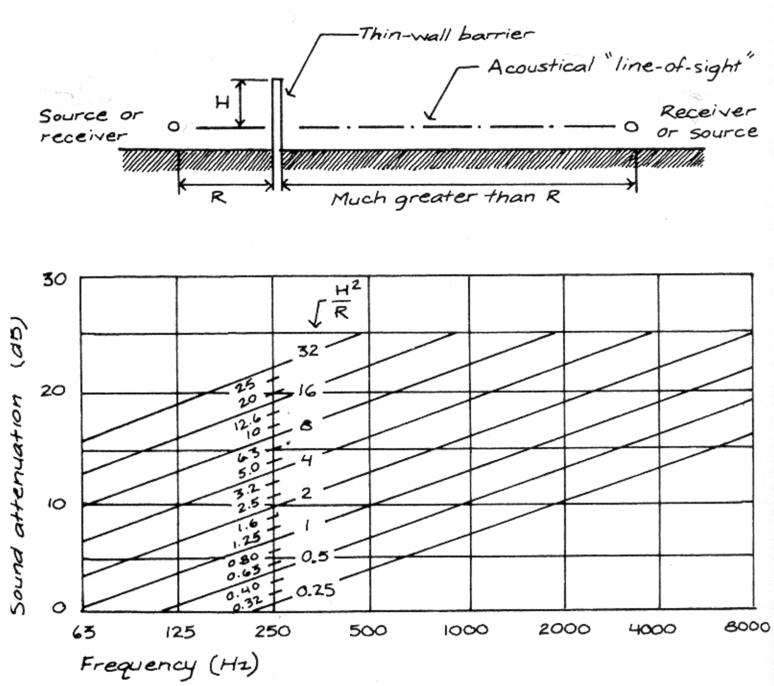


Figure D3.3.1 Thin-Wall Barrier Design Nomograph. Reprinted, by permission, from Egan, *Architectural Acoustics*, 256.

1. Design and draw a site section through a thin-wall barrier that mitigates one of your site-scale acoustic problems [B3.2 or D3.2].
2. Use the graph [Figure D3.3.1] to calculate the attenuation provided by your barrier.
3. Re-plot the site sound contours [B3.2] affected by your barrier.
4. Discuss the benefits and tradeoffs posed by your design in meeting Goal A. Indicate your choice of the best design resolution of this problem.

BUILDING SOUND RENDERING

Discussion

Activities within a building have the potential to interfere with each other acoustically. Your building should be zoned to acoustically separate activities. The zoning is successful only if the barriers between the zones are adequate. Remember, any opening, no matter how small, severely degrades the performance of an acoustic barrier. The space above a dropped ceiling is a notorious acoustic bridge between adjacent spaces.

Procedure

Evaluate how well your building attains Acoustic Schematic Design Goal B—**Sound conflicts in each space are avoided.**

1. Draw a schematic section through potentially conflicting spaces.
2. Identify the desired ambient sound level in each space [C3.1].
3. Represent the sound level in the potentially offensive room (source) and its transmission to the other room (recipient) through the acoustic barrier. Also represent the sound level in the recipient space.
4. Discuss your design strategies used for avoiding acoustic conflicts and any design changes you deem necessary to meet Goal B.

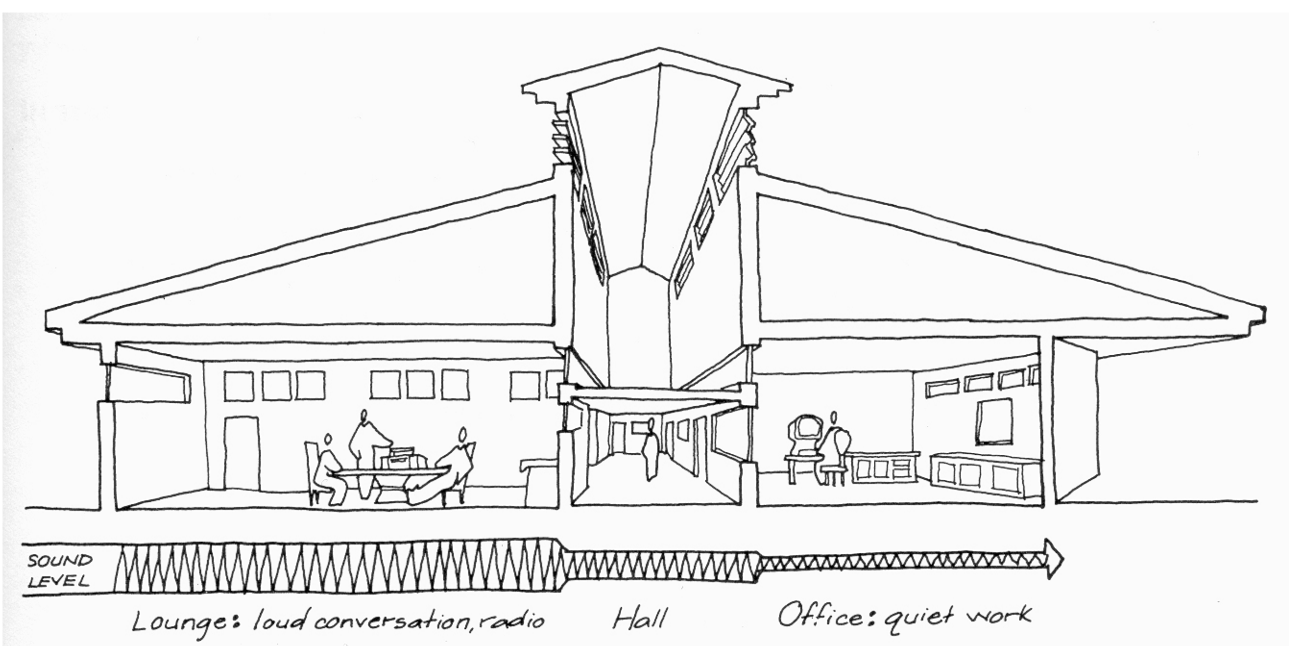


Figure D3.4.1 Acoustic Section. Linen supply office, Charleston, South Carolina.

DESIGN REVIEW

Discussion

You have formulated a schematic design for your building and site, studied potential sound conflicts at the site- and building-scales, chosen appropriate acoustic strategies, and ensured access to appropriate environmental forces. Each step has been accomplished independently and conflicting decisions may have been made. This design review affords you the opportunity to synthesize your cumulative design decisions.

Procedure

Review how well your design accomplishes Acoustic Schematic Design Goals A–B.

1. Make a schematic design sketch that combines all your acoustic design strategies. Indicate how and why your design has evolved in response to meeting D3.0 goals.
2. Annotate your drawings to describe the systems used and the changes made.
3. Discuss the tradeoffs among the acoustic, lighting, and thermal strategies that your design required. Also discuss situations where they worked effectively together.

E3 ACOUSTICS

DESIGN DEVELOPMENT

INTRODUCTION

Goals

Refine and further develop your building's acoustic design without sacrificing desirable views, daylighting, or thermal performance. Use your schematic design as the foundation for your design development.

Acoustic Design Development Goals

A. Appropriate interior materials and finishes make spaces acoustically comfortable.

B. Wall, ceiling, and floor construction details and finish materials combine to isolate acoustic zones.

Discussion

Rooms may be classified acoustically as being "dead," "neutral," or "live." "Live" rooms have predominantly hard surfaces such as wood, masonry, plaster, glass, concrete, and metal. These hard surfaces are acoustically reflective so that sounds created in the room stay "alive" for a long time by bouncing off the surfaces. Also, reflected sounds tend to blend with new sounds so that sound in a"live"room tends to be unintelligible or noisy. Rooms that are "live" seem excessively noisy and exciting.

"Dead" rooms have predominantly soft surfaces such as upholstery, drapes, acoustic tiles, carpets, and people. The soft surfaces are acoustically absorptive so that sounds created in the room are not reflected. Sounds in "dead" rooms are distinct and clear. Rooms that are "dead" seem excessively quiet and relaxing.

"Neutral" rooms seem neither "live" nor "dead."

Effective design should provide a variety of acoustic spaces that are appropriately "live," "neutral," or "dead." For example, a concert hall or basketball court should be "live" to enhance the music or the excitement, while a lounge should be "dead" to stress the serenity it provides, and a work environment should be "neutral" to reduce stress, yet encourage productivity.

In this section you will:

1. Complete the acoustic design development.
2. Calculate the room absorbency and resultant reverberation time for three spaces in your building to determine if they are acoustically appropriate.
3. Calculate the ambient sound level of an active space in your building to determine if it is within desirable limits.
4. Design acoustic barriers between acoustically conflicting spaces and determine if they reduce noise levels sufficiently.
5. Determine if natural ventilation causes an acoustic problem.
6. Critique your building's acoustic design.

Acoustic Design Development Strategies

Component-Scale Strategies

- Reflect and direct sound with **hard materials** (e.g., a concrete band shell directs the music to the audience).
- Absorb sound and prevent reflective echoes with absorptive materials (e.g., an upholstered back wall in a theatre prevents echoes).
- Absorb sound with acoustic materials in the ceiling plane when other surfaces must be reflective (e.g., thermal walls and floors are highly reflective).
- Use vertical, hanging acoustic panels in the ceiling when it must be thermally massive or when it must be exposed for aesthetic or daylighting purposes.
- Ensure that acoustic walls extend from floor to ceiling to prevent sound leaking over the wall (especially through a dropped ceiling).
- Provide acoustic barriers between adjacent spaces with very different NCs (greater than 5 decibels apart) or with NCs less than 40 decibels.
- Prevent overheard conversations in adjacent, private spaces with an acoustic barrier.
- Reduce sound transmission by adding mass to a wall or by providing structural discontinuity (e.g., a double wall).
- Choose different materials for different purposes. Materials chosen for high sound absorption will generally have little value as sound barriers, due to their porous and lightweight character.

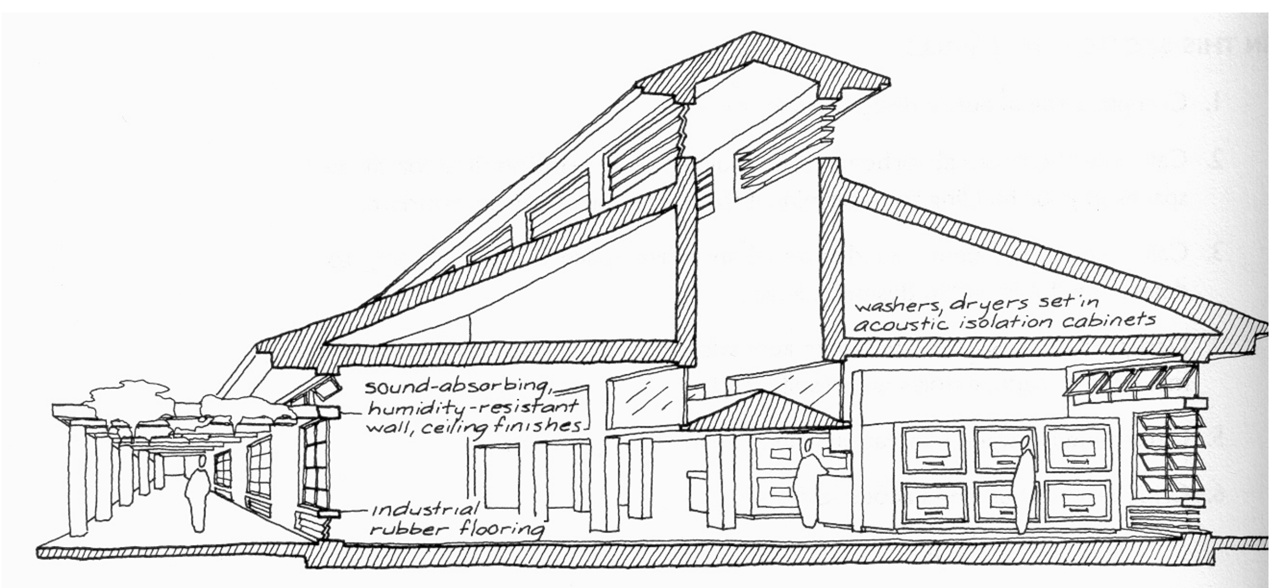


Figure E3.1.1 Acoustic Details. Linen supply, Charleston, South Carolina.

DESIGN (continued)

Procedure

Refine your schematic design [D3] to include component design considerations. Choose three spaces in your building for these acoustic studies. Select either a large room that has multiple sound sources (such as 16 cash registers) or a large room that has the acoustic goal of silence (such as a lecture hall or sanctuary). Also select two adjacent rooms that require an acoustic barrier between them.

Use the appropriate strategies to aid your acoustic design development. Develop details for your acoustic design in the three spaces you have selected. Make an educated guess of proper finish materials and surfaces to create appropriately "live," "neutral," or "dead" spaces.

Summarize your selections and design intentions.

Space	Reason for Selection	"Live," "Neutral," or "Dead"	Why?

Modify your schematic design drawings to include the components you have developed. Indicate clearly on your drawings intended acoustic design strategies.

Document your design as follows:

1. Sectional perspective of each room, indicating finish materials, surfaces, and furnishings (scale: 1/8" = 1'-0").
2. Wall or floor/ceiling section, showing the acoustic barrier between adjacent rooms (scale: ¾" = 1'-0").

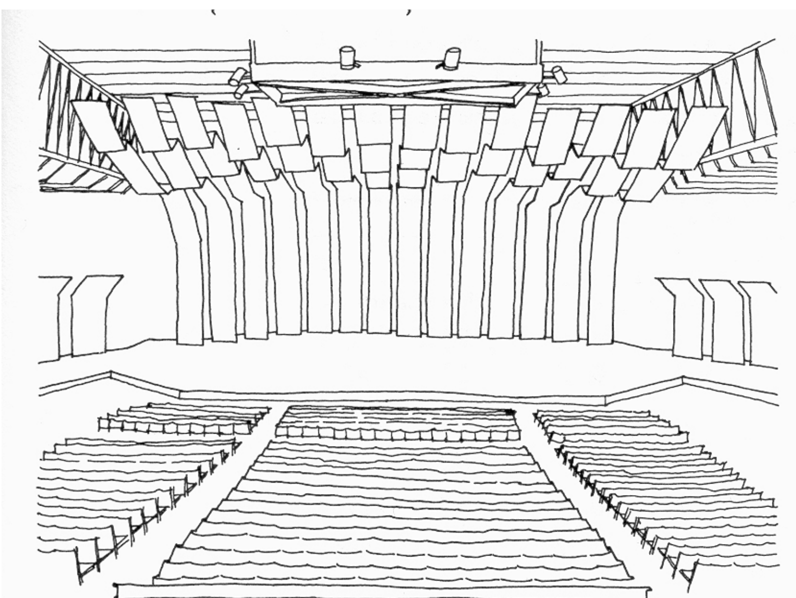


Figure E3.1.2 Adjustable Acoustic System. Concert Theatre, C.W. Post Center, Greenvale, New York, Mitchell/Giurgola (architects), 1982.

DESIGN DEVELOPMENT
ROOM ABSORBENCY

Discussion

In order to determine how acoustically "live" a space is, its total absorbency must be calculated. Absorbency is measured in Sabins and can be calculated

$$A = (\alpha)\ (a),$$

where:

A = absorbency (Sabins)

α = coefficient of absorption

a = surface area (ft^2).

Total room absorbency is simply the sum of the absorbency of all the surfaces, furnishings, and people in the room. Normally, absorbency is measured at the mid-range for human speech (500 hertz). However, your space has a different characteristic sound (e.g., the whir of blenders, the cry of infants, the bleating of sheep), do your calculations using the appropriate frequency [*MEEB,* Figure 22.8, p.1023]. If the space has operable windows, calculate for both open and closed windows. An open window is totally absorptive (α = 1.0) but provides no acoustic barrier to sound. If a floor is densely covered by occupants, as in a fully occupied theatre or classroom, calculate the absorbency of the occupants, not the floor absorbency.

Procedure

Evaluate how well your design attains Acoustic Design Development Goal A—**Appropriate interior materials and finishes make spaces acoustically comfortable.**

For each of the three rooms selected:

1. Calculate the room absorbency. Use the coefficients of absorption [*MEEB,* Table 23.1, p.1045]. Include considerations for the occupants and furnishings, since they may significantly alter the room's acoustics (e.g., a bare apartment compared with a furnished one).

Absorbency Calculation [suggested format]

Room ______________________ Volume ____________________ ft^3

Surface	Material	Area (ft^2)	Absorption open	Absorption closed	Absorbency (S) open	Absorbency (S) closed
ceiling	*parquet*	*550*	*N/A*	*0.10*	*55*	*55*
occupants	*25 students*	*550*	*N/A*	*0.50*	*275*	*275*
walls	*sliding glass*	*475*	*1.0*	*0.04*	*475*	*19*
	fixed glass	*475*	*N/A*	*0.04*	*19*	*19*
				TOTAL	*824*	*368*

ROOM ABSORBENCY (continued)

2. Evaluate the liveness of your spaces using the room liveness graph [Figure E3.2.1].
3. If your room acoustics are not appropriate for the space [step 2], redesign for more or less absorption, and redo steps 1 and 2.
4. Make a schematic diagram illustrating the design changes that you deem necessary to meet Goal A, or comment on the appropriateness of your design.

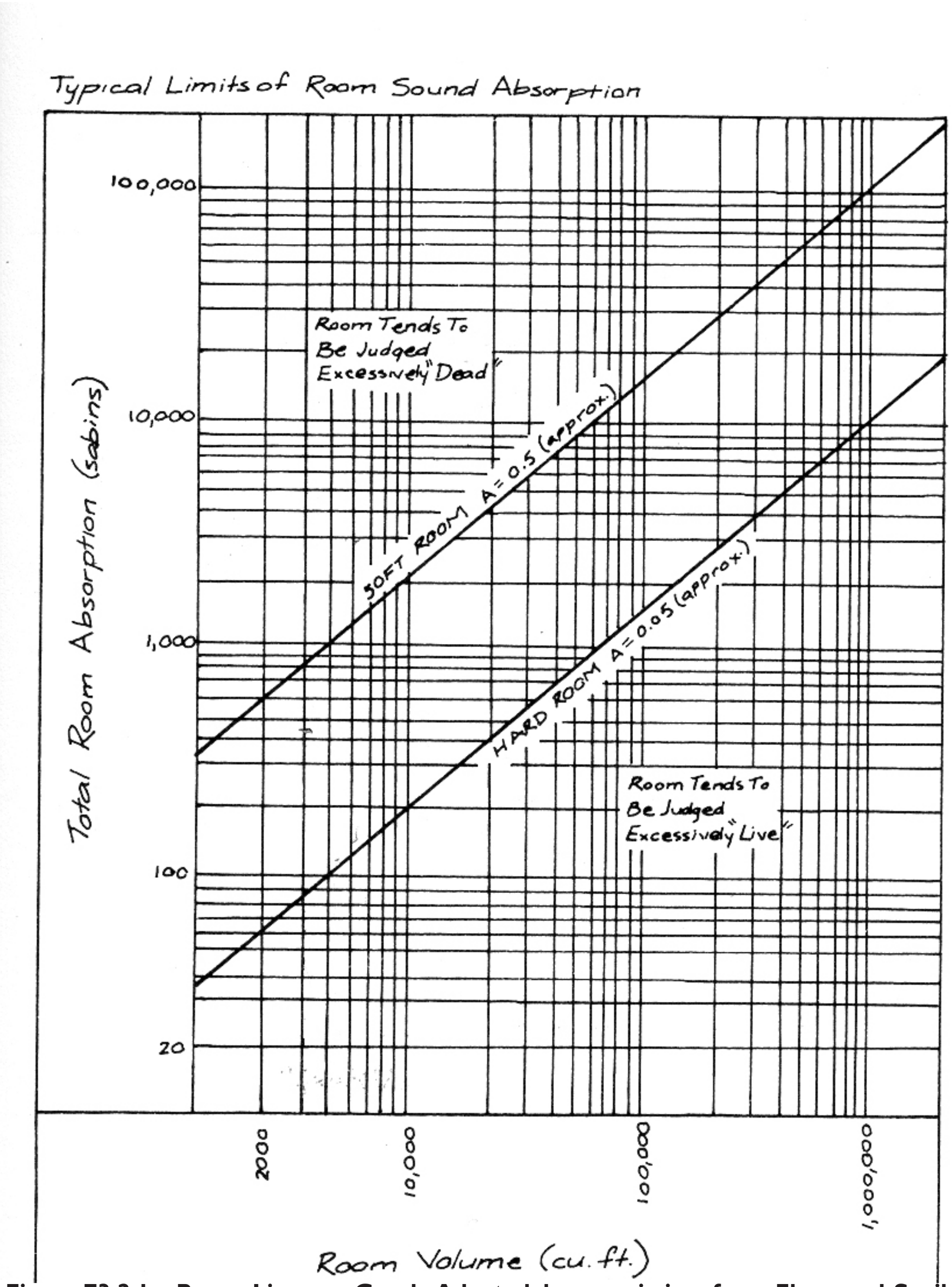


Figure E3.2.1 Room Liveness Graph. Adapted, by permission, from Flynn and Segil, *Architectural Interior Systems*, 66.

REVERBERATION TIME **E3.3**

Discussion

Room reverberance is a factor in evaluating the suitability of a space for its function. Function can be categorized by two acoustic goals—silence and quiet.

Silence-goal rooms are designed for a monarchy of sound. One sound source dominates the room (e.g., a lecture hall, a symphony hall, a theatre, or a church). For silence-goal rooms, the reverberation time is critical in determining the fit between the room and its activities.

Quiet-goal rooms are designed for a democracy of sound. No single sound source dominates the room, so all sounds produced blend to form the background noise. Also, the room may support multiple activities (e.g., offices, supermarkets, libraries, and bowling alleys). For quiet-goal rooms, the reverberation time is useful in determining noise control characteristics.

Generally, "live" rooms have longer reverberation times than "dead" rooms and are more appropriate to silence-goal activities. Among silence-goal activities, musical performance requires longer reverberation times than speech.

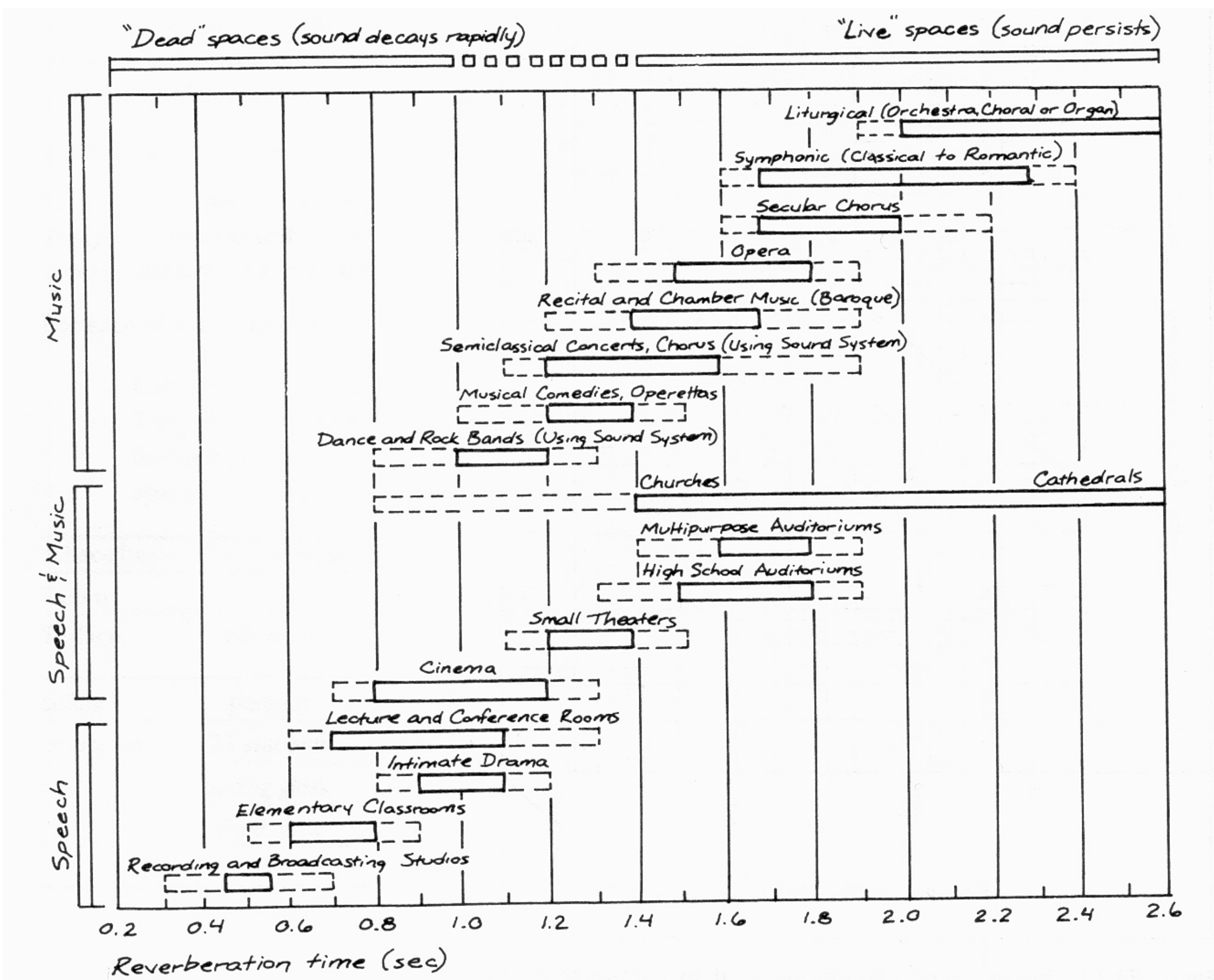


Figure E3.3.1 Recommended Reverberation Times. Adapted, by permission, from Egan, *Architectural Acoustics*, 64.

DESIGN DEVELOPMENT

REVERBERATION TIME (continued)

Procedure

Evaluate how well your room attains Acoustic Design Development Goal A— **Appropriate interior materials and finishes make spaces acoustically comfortable.**

1. Determine the recommended reverberation time, T_R, for your spaces [Figure E3.3.1 or *MEEB,* Figures 23.16, p.1060]. If you cannot determine a recommended T_R, make a note to that effect, and make an educated guess.
2. Calculate the T_R for your spaces.

   T_R = [(.049)(volume)] / (absorbency)

Reverberation Time [suggested format]

Space	Recommended T_R (seconds)	Volume (ft^3)	Absorbency (Sabins)	Actual T_R (seconds)
lecture hall	*.7–1.1*	*7,200*	*350*	*1.0*

3. Discuss the design changes that you deem necessary to meet Goal A, or comment on the appropriateness of your design.

ROOM SOUND LEVEL E3.4

Discussion

When a room has several sound sources, it should be tuned acoustically to keep the sound level within limits as specified by its noise criteria (NC). Tuning a room is a function of the volume of the room and its reverberation time. Volume can be adjusted by changing the ceiling height, while T_R can be adjusted by changing either the volume or the absorbency of the room's materials.

The amount of sound generated is measured by the source's sound power level, L_W. This measurement is not dependent on the source being enclosed. The amount of sound generated in a specific room can be calculated, given the source's L_W and the room's T_R and volume. This measurement is the sound pressure level, L_P.

For more information

Egan, *Architectural Acoustics*, Appendix C, pp.398–399.

Procedure

Evaluate how well your room attains Acoustic Design Development Goal A—**Appropriate interior materials and finishes make spaces acoustically comfortable.**

For the room with multiple sound sources:

1. Make a schematic diagram of the space, identifying the sound sources, their L_W, and frequency band. Determine L_W [*MEEB*, Figure 22.8 p.1023 & Table 22.5, p.1032].

   NOTE: The information in *MEEB* designated SPL or dBA is L_W, since it is not room-specific.

2. Determine the allowable decibel level at 500 hertz [C3.1 or *MEEB*, Table 24.8, p.1107].

3. Determine the sound pressure level, L_P, of each individual sound source. The value for $(L_P - L_W)$ is on the vertical axis of Figure E3.4.1.

   $L_P = L_W + (L_P - L_W)$

Room Sound Sources [suggested format]

Sound Source	L_W (dB)	Hz	T_R (seconds)	Volume (ft^3)	L_P (dB)	NC (dB)
stereo, teenager	*82*	*500*	*0.8*	*1,200*	*80*	*65*

ROOM SOUND LEVEL (continued)

4. Calculate the total sound level in the space by "adding" L_P for all sound sources. Use Figure B3.1.2 as a nomograph for adding decibels.

   List the sound pressure level of the sound sources from the highest to the lowest, and add them incrementally.

Total Sound Level Calculation [suggested format]

Source	L_P (dB)	ΔL_P (dB)	Add dBs	**TOTAL** L_P (dB)
stereo #1	*80*			*80.00*
stereo #2	*80*	*0*	*3.00*	*83.00*
parent's voice	*77*	*6*	*1.28*	*84.28*

NOTE: The total sound pressure level may be calculated mathematically from the formula that defines decibels. If each L_P is converted to watts/cm² [*MEEB,* Table 22.3, p.1026], then

total $L_P = 10 \log [(\sum L_P) / (10^{-16})]$.

If you use this method, show your work.

5. Does your space meet the recommended noise criteria? Explain how your design must evolve to meet this criteria and Goal A.

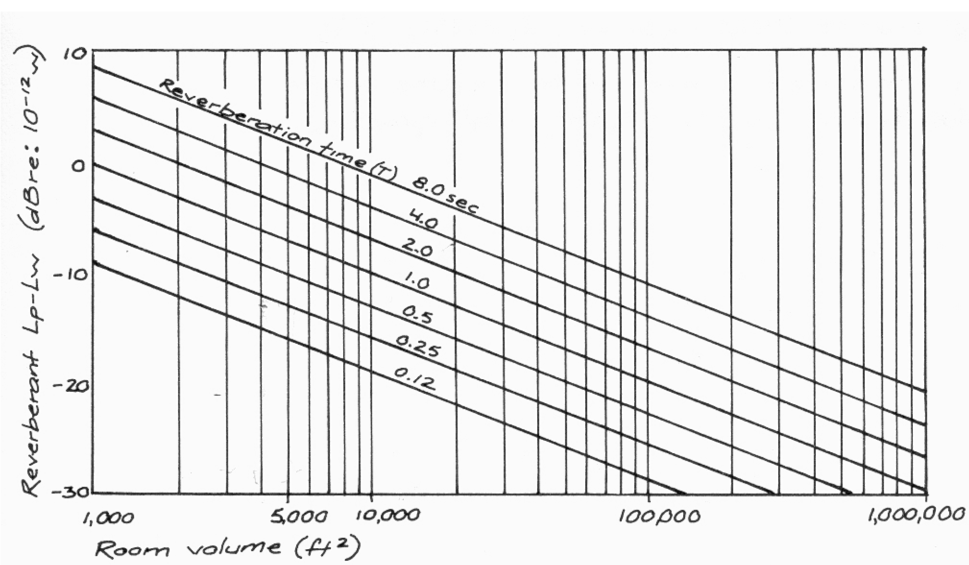


Figure E3.4.1 **Reverberant $L_P - L_W$ Nomograph. Adapted, by permission, from Egan, *Architectural Acoustics*, 399.**

STC RATINGS

Discussion

The sound transmission class (STC) of a wall is based on its ability to reduce the decibel level of audible sound at all frequencies as the sound passes through the wall.

STC Rule-of-Thumb	
STC 35	Normal speech can be heard and understood through the barrier.
STC 40	Normal speech is heard as a murmur through the barrier.
STC 50	Very loud sounds can be heard only faintly through the barrier.

For design purposes, sound is reduced by 35 decibels as it passes through an STC 35 wall. A wall with an opening or a door usually has a significantly lower STC than a similar, solid wall.

For more information

MEEB, Section 24.11, pp.1090–1091 (STC definition).

Procedure

Evaluate how well your wall construction attains Acoustic Design Development Goal B—**Wall, ceiling, and floor construction details and finish materials combine to isolate acoustic zones.**

1. Choose at least two walls to evaluate—one a solid wall and the other a wall with an opening. One of these walls should be the barrier between the two rooms you chose in E3.1. On a sketch of your floor plan indicate where these walls are located.
2. For the solid wall:
   a. Find the recommended STC [*MEEB*, Tables 24.13–24.15, pp.1129–1130].
   b. Select appropriate barriers [*MEEB*, Appendix K, pp.1771–1790].
   c. Sketch the barrier constructions. List the STC for each barrier and the transmission loss (TL) at 500 hertz or at a frequency crucial for your design.

DESIGN DEVELOPMENT

STC RATINGS (continued)

3. For the wall with openings:

   a. Select an appropriate door or window configuration [*MEEB*, Tables 24.3 and 24.4, pp.1095 and 1098].

   b. Sketch the wall and list the STC and TL at 500 hertz.

   c. Calculate the composite STC and TL for this wall [*MEEB*, Figures 24.22–24.23, p.1093].

NOTE: The highest composite TL attainable with a hole in a wall is 28.

STC of Acoustic Barriers [suggested format]

Barrier Description	Area	Recommended STC	Actual STC	TL @ 500 Hz	Composite STC	Composite TL
staggered wood stud wall	*120*	*40*	*44*	*45*		
pass-through (1' x 2')	*2*	*40*	*0*	*0*	*28*	*28*

4. Discuss decisions you made as a result of this evaluation and any design changes you deem necessary to meet Goal B.

OUTDOOR SOUND AND VENTILATION

Discussion

Ventilation apertures allow free movement of air for heat removal, but also allow sound to readily enter the building. Remember, a noisy room in a building may transmit sound to another room across an outdoor space when both are being naturally ventilated. The conflict between ventilation and sound control must be identified and resolved at the site scale with external noise barriers, at the building scale with appropriate acoustic zoning, or at the component scale with adequate, switchable barriers.

Procedure

Evaluate how well your room attains Acoustic Design Development Goal B—**Wall, ceiling, and floor construction details and finish materials combine to isolate acoustic zones.**

1. Select a room that uses windows to naturally ventilate on the noisiest side of the building (use the site sound contours [B3.1] to select this room).
2. Establish the sound level outside the window of the room you have selected. Consider only constant noises, like those from a freeway or an overly noisy room.
3. Record the recommended NC for your room [*MEEB*, Table 24.8, p.1107].
4. Calculate the percentage of the wall that is open window. Note the transmission loss through the solid part of the wall. Find the resulting sound level inside the space [*MEEB,* Figure 24.23, p1093].

Sound Level through Ventilation Openings [suggested format]

Space	Sound Level Outside Window (dB)	Recommended NC (dB)	Wall TL or STC (dB)	Open Window (%)	Resulting TL (dB)	Resulting Inside Sound Level (dB)
office	*65*	*30–35*	*45*	*10*	*10*	*55*

5. If the recommended NC isn't met, discuss the design alternatives necessary to meet Goal B.

DESIGN REVIEW

Discussion

You have just completed acoustic design development for a few important spaces in your building. The methods you have used should give you some insight for successful acoustic design for the rest of the building. This design review affords you the opportunity to view your acoustic design holistically and to discuss the conflicts and tradeoffs with other design considerations for the entire building.

Procedure

1. Compare the developed design with the schematic design [D3]. Discuss how it has evolved and why.
2. You have explored the use of acoustic, daylighting, and thermal strategies. Comment on what tradeoffs have been made and what strategies worked well together.
3. Illustrate your discussion of points (1) and (2) with annotated, schematic diagrams of your acoustic design for the entire building.